WEPROG

Weather & wind Energy PROGnoses

Increasing the Competition on Reserve for Balancing Wind Power with the help of Ensemble Forecasts

10th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants to be held in Aarhus, Denmark
October 2011

Including physical Uncertainty from Ensembles

TABLE OF CONTENTS

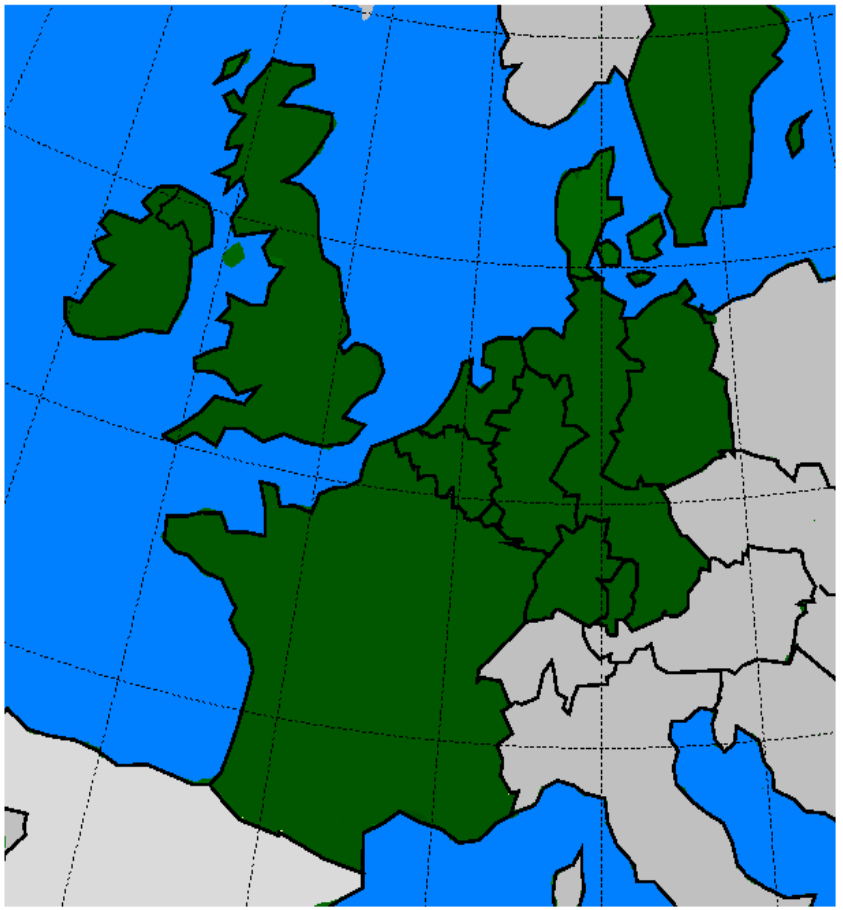
DEWEPS SuperGrid Study

WEPROG – Weather & wind Energy PROGnoses

Study 2010: „SuperGrid" Simulations

=> countries with similar weather influences

=> Offshore wind power will connect these Countries even more



MAIN RESULTS

=> Permanently ca. 600-700MW less day ahead forecast error on wind power with an extended area in comparison to the individual countries

=> Remaining Question: This result is encouraging, but can we confirm the results in a study with more precise standing data and actual generation ?

Paper and Presentation can be found on our web page:
http://download.weprog.com/moehrlen_dewek2010_s10_p4.pdf
http://download.weprog.com/moehrlen_presentation_dewek2010_s10_p4.pdf

A reduced problem size: simulation of cross-border balancing of aggregated Danish and German wind power

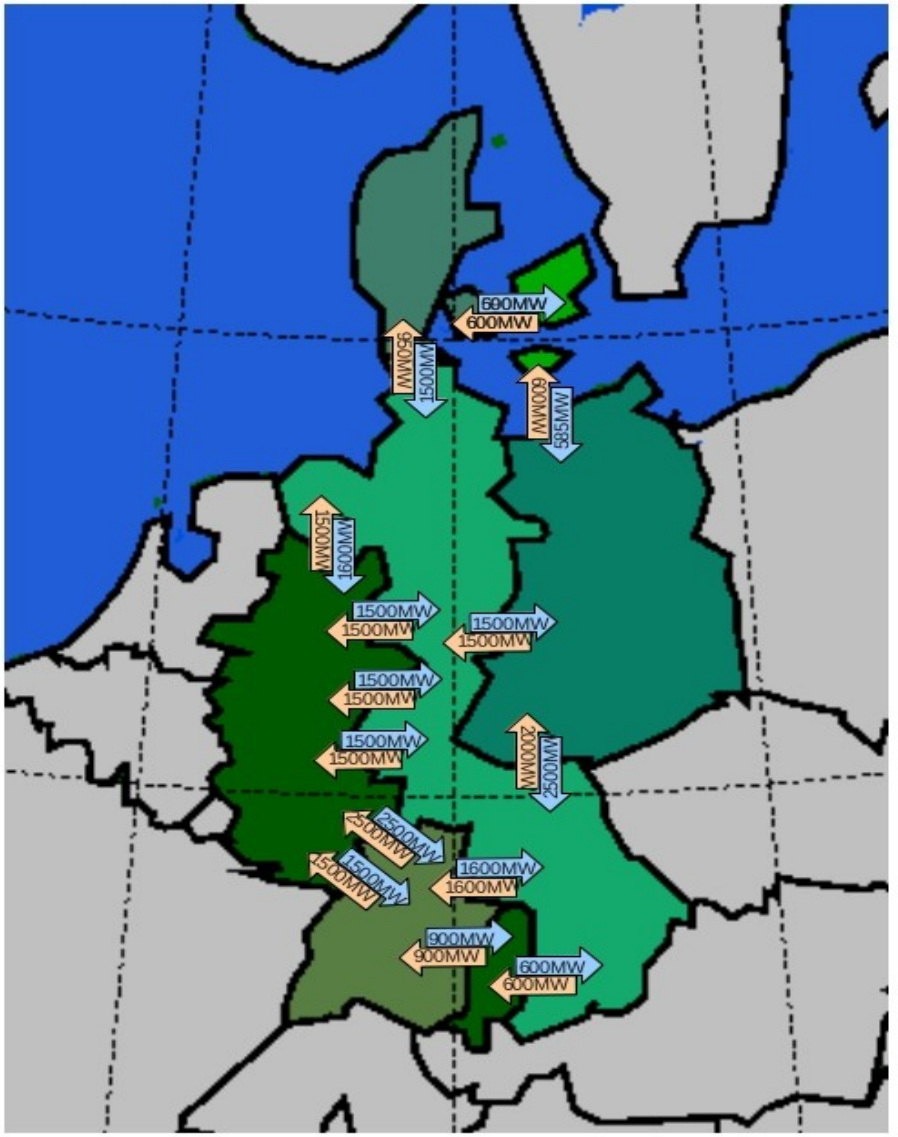
Demonstration targets:

1. **Verification of benefits of area aggregation with "real data"**
   Quantification using actual standing data and published on-line generation

2. **Verification of a new short-term forecast technique using objective uncertainty**
   Effective pre-balancing wind power on the 2-hour horizon using the intraday market with a minimal of "double trading"

3. **Introduction of a *conditional bidding scheme* as second spot market auction**
   Scheme is designed for maximum competition also during congestion

4. **Dynamic reserve allocation**
   Estimate the potential reserve reduction for a large dispersed pool of wind power



What is the impact of an enlarged Aggregation Area of wind power?

1. **Better frequency distribution** of generation and correlation to demand
2. **Less variable generation** (+ forecast), which is easier to manage in the intraday market
3. **Less price volatility**, less start/stop on scheduled generation, lower marginal costs
4. **Smaller forecast errors** in the day-ahead and intra-day market
5. **Part of the forecast error will be hidden** and balanced inside the enlarged area

Assumptions in the *cross-border-balancing* study

1. The **capacity** of the forecasts were **kept constant** over the year and set as of Jan 2011. Hornsrev 2 offshore farm was added 1. Oct. 2010

2. Public **measurements were scaled to Jan 2011 level** with some approximations on DK1 because of strong impact of Hornsrev 2.

3. **Public upscaled measurements** were treated as **"true values"**

4. **Artificial upscaled "online" measurements** for short-term forecasts were generated from public measurements by adding 2 different random error contributions (0.77% and 0.5% of inst. capacity) and taking the average of these

5. **Denmark and Germany are one price area** – no flow to SE and NO – and interconnectors are available for balancing forecast errors

Data used for the *cross-border-balancing study*

Measurements: July 2010 – June 2011
Denmark: DK1 + DK2 public measurements from Energinet.dk
Germany: published at the websites of the 4 TSOs

Experiment setup: 6 areas (2 Denmark, 4 Germany)
Capacity: 32GW
Online Measurement capacity: ca. 5GW
Geographic area: 1200 x 600 km

Forecasts
Day-ahead forecasts (**DFC**), raw intra-day forecast updates (**rSFC**):
75 weather forecasts from WEPROG's MSEPS low resolution model system

Short-term forecasts with measurement influence (**SFC**):
WEPROG's inverted Ensemble Kalman Filter (iEnKF)

Inter-connector size, position and flow:
Public data from the TSO's (e.g. Transmission measurements for the DE-DK interconnectors from Energinet.dk, Regionenmodell "Stromtransport 2013" from German TSO's)

Determining Forecast Uncertainty

The forecast uncertainty is a crucial part for system area imbalance exchange

1. Step: Compute the **average error** of the uncorrected short-term Forecast
   EA = 1/N Σ (SFC – OBS)
2. Step: Compute the Ensemble Spread (ESP) and the Correlation (ESP,FC_ERR)

3. Define the Pool Forecast Uncertainty PFU

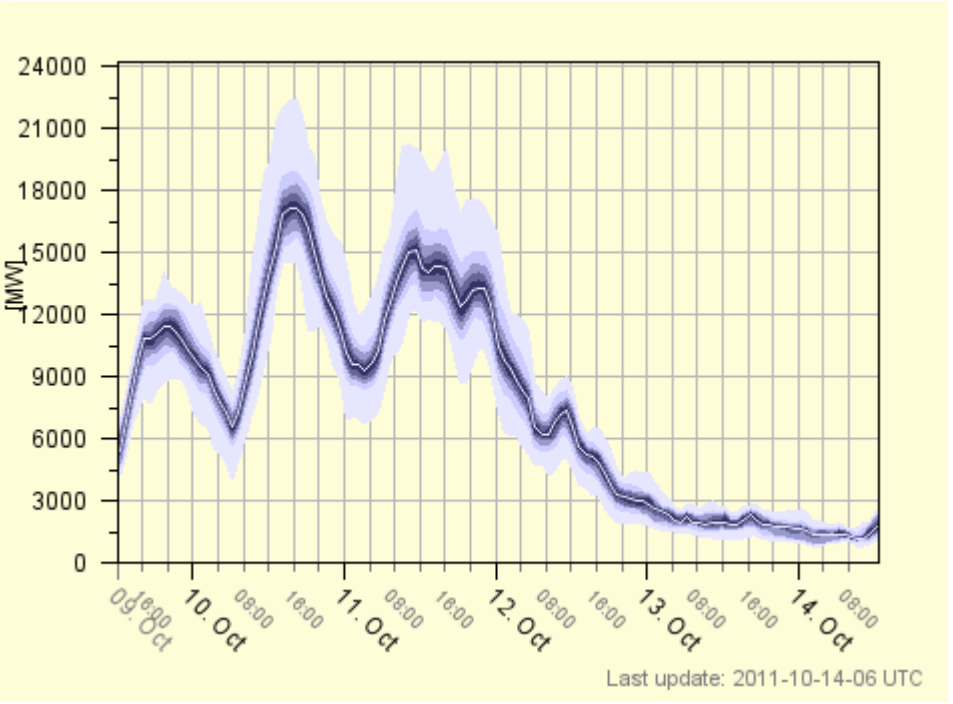
   a) weather unrelated uncertainty (e.g. turbine conditions, availability, etc.)
   b) **weather related uncertainty** (best modelled with an Ensemble)

$$PFU = \underbrace{C \cdot F_{ESP}}_{\text{Weather related uncertainty}} + \underbrace{(1-C) \cdot EA}_{\text{weather unrelated uncertainty}}$$

F_{EPS} = ESP · EA/ESPM = scaling factor for percentile difference historic/real-time

ESP=real-time Ensemble Spread
ESPM=mean of ESP over 1 year

C= correlation of ensemble spread ESP and FC Error



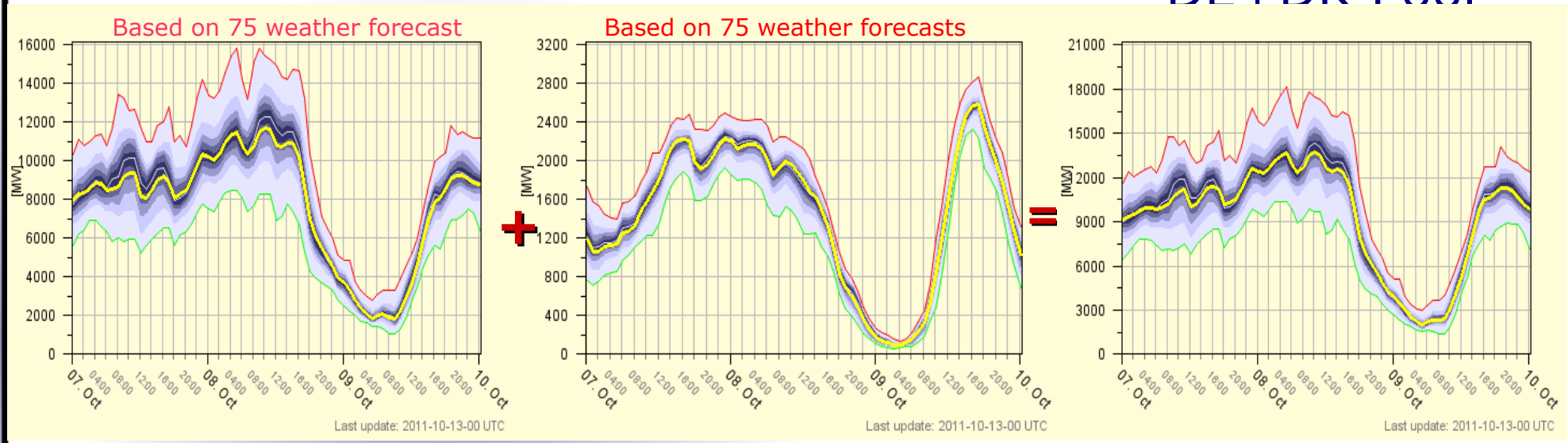
Examples Forecasts

WEPROG – Weather & wind Energy PROGnoses

Wind DE

Wind DK

DE+DK Pool



=> computation of the entire DE+DK Pool to take advantage of smoothing effects

=> Uncertainty computations are nearly always better on the total pool:

„spread(DE) + spread(DK) >= spread(DK+DE)"

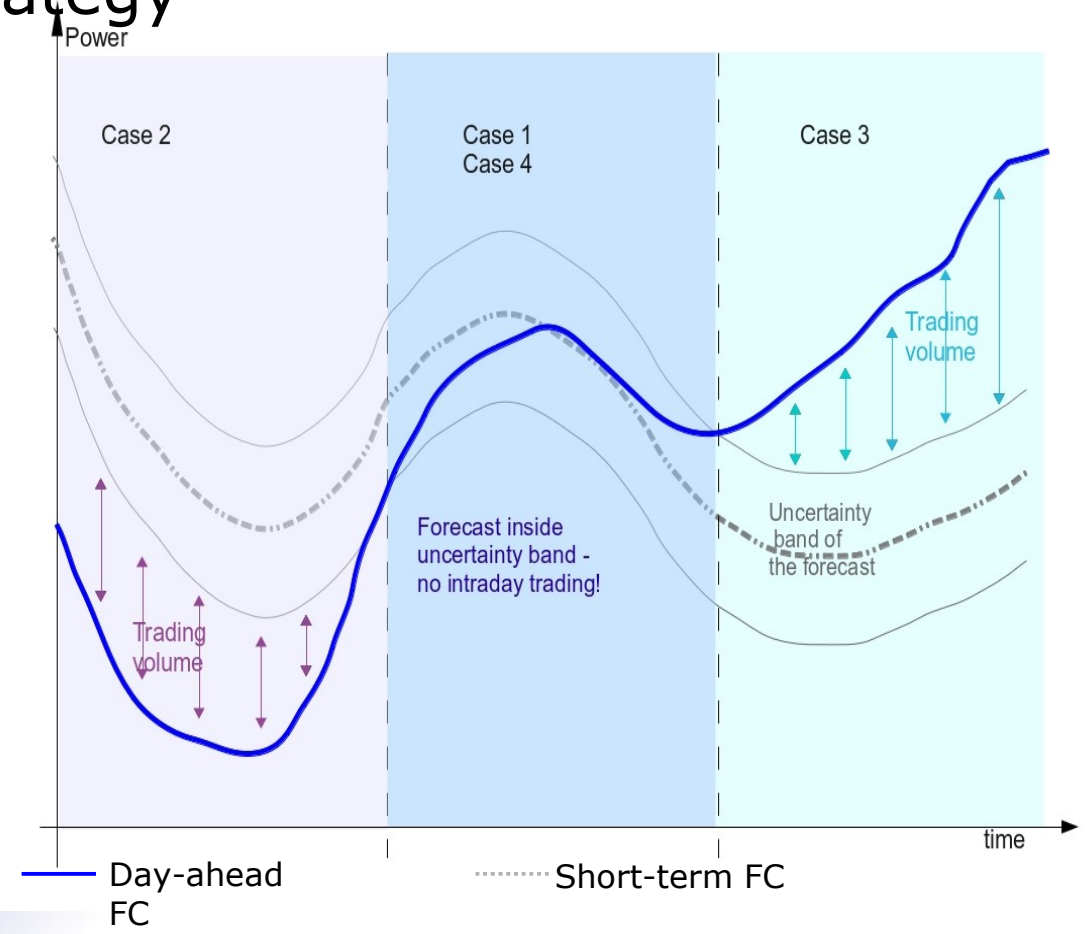
Intra-day forecasting strategy

Expected Balance:
EB = SFC - DFC

where SFC is short-term forecast,
DFC is the Day-ahead Forecast

Absolute Balance:
AB = |SFC – DFC| - PFU

where PFU is the
"power forecast uncertainty"



Computation of the balancing volume for the Foreground Generation Correction Forecast:

FGCF = a * SFC + b * PFU - c * DFC

CASE	EB	AB	FUP	a,b,c
1	<0	<0	DFC	0,0,0
2	>=0	>0	SFC-PFU	1,-1,1
3	<0	>0	SFC+PFU	1,1,1
4	>=0	<0	DFC	0,0,0

Statistical results from a one year cross-border-balancing simulation

RMSE

Area	DFC [%inst.cap]	rSFC [%inst.cap]	SFC [%inst.cap]	Persistence [%inst.cap]	SFC + PFU [%inst.cap]	Hidden Error [%inst.cap]
DK1	7.98	5.74	5.39	5.35	-	7.19
DK2	10.75	7.87	7.73	7.23	-	9.59
DE_50H	6.51	4.89	3.91	4.32	-	3.57
DE_TTG	5.97	4.49	3.69	4.00	-	3.13
DE_AMP	5.54	4.33	3.98	4.35	-	4.77
DE_ENBW	5.14	4.60	4.67	3.81	-	6.29
DE	4.96	3.54	2.53	3.28	-	0.95
DK+DE	4.79	3.39	**2.29**	3.13	**3.69**	0
Imbalance Reduction in [MW]	704	622	787			

- Permanent lower imbalances in DK and DE from extension

- largest improvement from extension of area at the SFC
  =>considerable part of error lies in online estimation ?!

- RMSE above 4% only 0.6% of time, RMSE < 2% found in 92% of time
  => 50% errors < 2% help the system!

- RMSE(DFC,OBS)-RMSE(SFC,OBS)=2.5%, but RMSE(DFC,SFC) is 3.79%
  ==> 1.29% are corrections in the wrong direction that impose unnecessary costs with permanent trading with SFC !

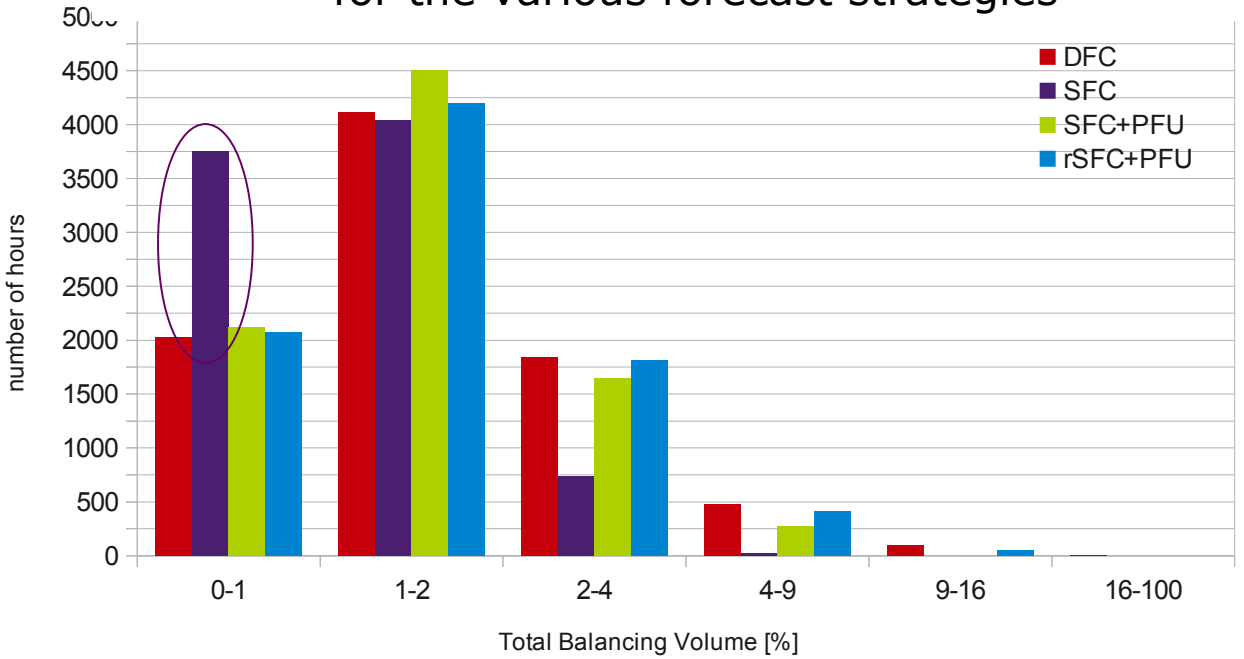
Effective Balancing Volume and Error Distribution

Forecast type / Unit [%inst. Cap]	Intra-day Trading	% of time with small errors	Effective Volume *	Double Trading
Upscaled Obs	0.00	100	0.00	0.00
SFC	2.56	91	3.51	0.82*
SFC+PFU	0.61	77	2.69	0.03
DFC	0.00	71	2.70	0.00
rSFC	2.20	81	3.99	1.30
rSFC+PFU	0.22	73	2.70	0.02

*Effective Trading Volume=
the Volume that is effectively traded at the market, which is the average of 2 Upscaling simulations minus 50% of the small errors.

* MAE equivalent to 1.29% RMSE

Frequency distribution of the total balancing volume for the various forecast strategies



Note: the SFC has disappointing many hours in the 1-2% bin, considering that a correction to DFC is applied every hour!

DFC=day-ahead FC / SFC=iEnKF short-term FC with measurement / rSFC=raw short-term FC – PFU=prob. FC uncertainty

Dynamic Reserve Prediction

PREDICTABILITY OF ERRORS

predictability of errors = correlation (MAE,Ensemble Spread)

- Predictability of **SFC** error **day-ahead** is 0.43
  - => although SFC is stirred by not yet known measurements, almost half of the error is predictable one day in advance
  - => provides savings, if used to pre-allocate reserves day-ahead!
  - => will be important, if wind power error reaches reserve limit

- Predictability of **SFC 2h in advance** only increases to 0.53 (+10%)
  - => 0.47 is random uncertainty, not weather related !

WEPROG – Weather & wind Energy PROGnoses

Simulation of a ***Conditional Bidding Scheme*** used to maximise competition on Intra-day trading and Reserve

Results from **50 hours full import** and **50 hours full export**:

=> error increase by choosing upper/lower band in times of congestion risk:
0.02% of capacity averaged over 1 year
or
1.75% of capacity during 100 hours of extreme conditions

Proposed Strategy for the market:
Price takers can add an **upper and lower band** in volume to the spot market bid

The market operator performs a *second iteration in the event of*

A) **full import -> the lower band** is applied

B) **full export -> the upper band** is applied

Benefits:
=> cost effective and fair solution to maximize competition
=> leads to improved total large scale system balance with a fair and simple extension to the price and flow calculations

Summary of the main results from the *cross-border-balancing* study

➔ **too much erroneous volume traded, if all differences** between DFC and SFC **are traded** in the intra-day market

➔ both „**pool forecast uncertainty**" forecasts only **correct for the large errors** of the Day-ahead forecast –> **NO double trading** !

➔ The SFC+PFU forecast gains from the fact that **a large amount of the small errors help the total system** and hence reduce costs!

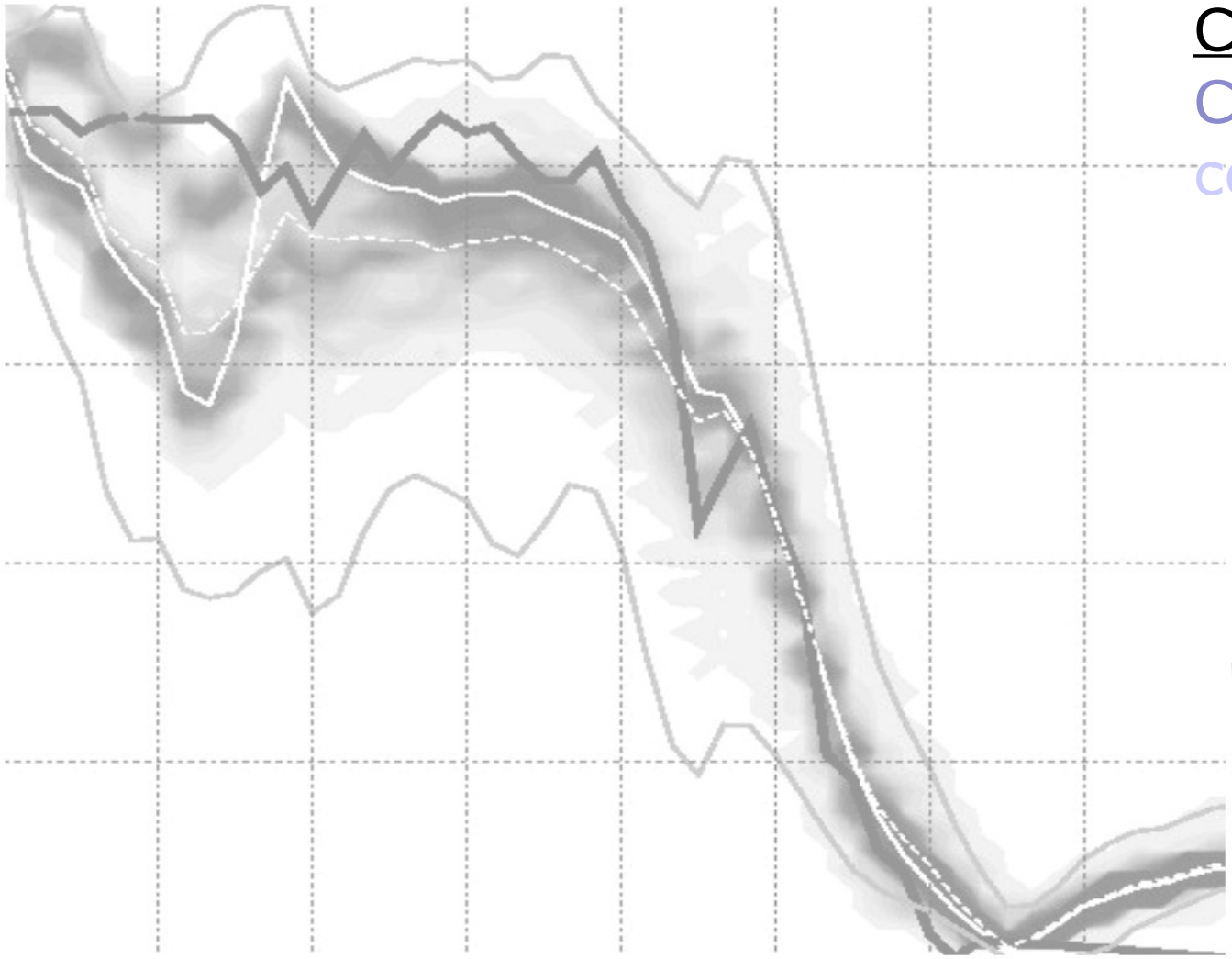
➔ "**Conditional Bidding Scheme**" can be used to **pre-allocate** inter-connector **capacity day-head** and thereby increase competition

By applying uncertainty based forecasting tools both DK + DE benefit from cross-border balancing of wind power:

- reduced errors
- higher system security
- lower prices

WEPROG – Weather & wind Energy PROGnoses

Thank you for your attention !



Contact:
Corinna Möhrlen
com@weprog.com

Contact:
WEPROG ApS Denmark
Aahaven 5
5631 Ebberup
Tel. +45 64 71 17 63
Fax: +45 6471 2094

WEPROG GmbH Germany
Eschenweg 8
71155 Altdorf
Tel. +49 (0)7031 414279
Fax. +49(0)7031 414280

Email: info@weprog.com
Web: www.weprog.com